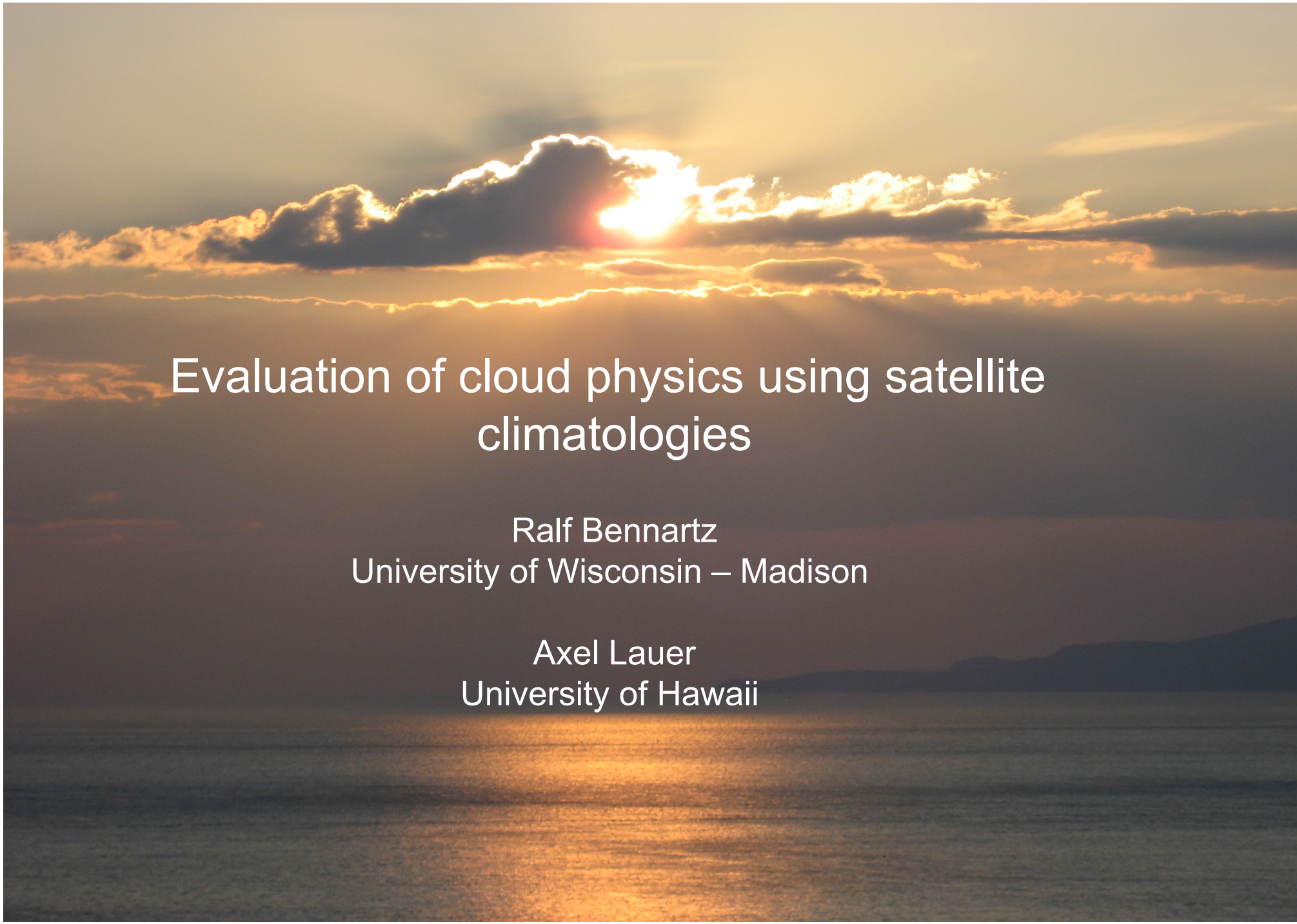


Evaluation of cloud physics using satellite climatologies

Ralf Bennartz
University of Wisconsin – Madison

Axel Lauer
University of Hawaii

Outline

- Satellite climatologies
- Activation
- Autoconversion and accretion
- The diurnal cycle
- Conclusions

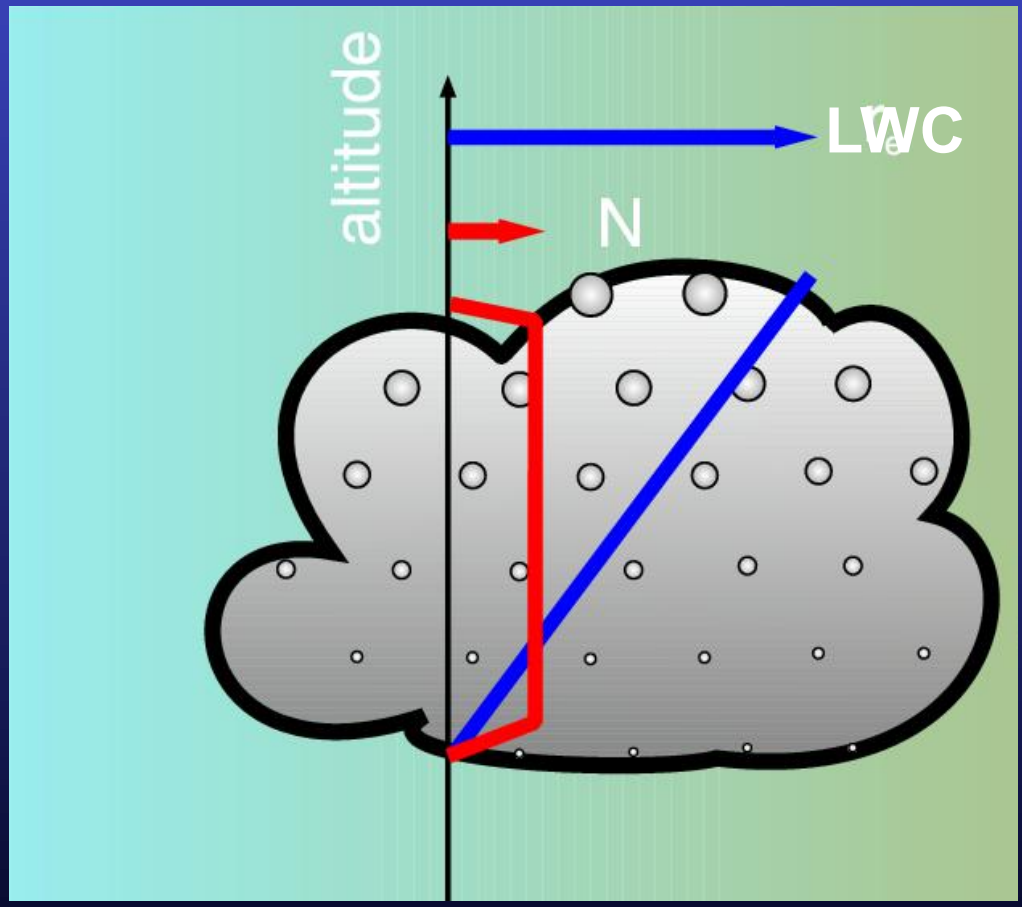
Satellite climatologies

- Cloud droplet number concentration (N)
- Liquid water path (LWP)
- Drizzle/rain? Rain water path (RWP)
- Cloud fraction
- Albedo

Satellite climatologies

- Cloud droplet number concentration (N)
- Liquid water path (LWP)
- Drizzle/rain? Rain water path (RWP)
- Cloud fraction
- Albedo

(Sub) adiabatic stratiform clouds



Basic physical relations

Three input variables (τ_{VIS} r_{eff} τ_{MW})

→

Three output variables (N,LWP,RWP)

Basic physical relations

Three input variables (τ_{VIS} r_{eff} τ_{MW})

→

Three output variables (N,LWP,RWP)

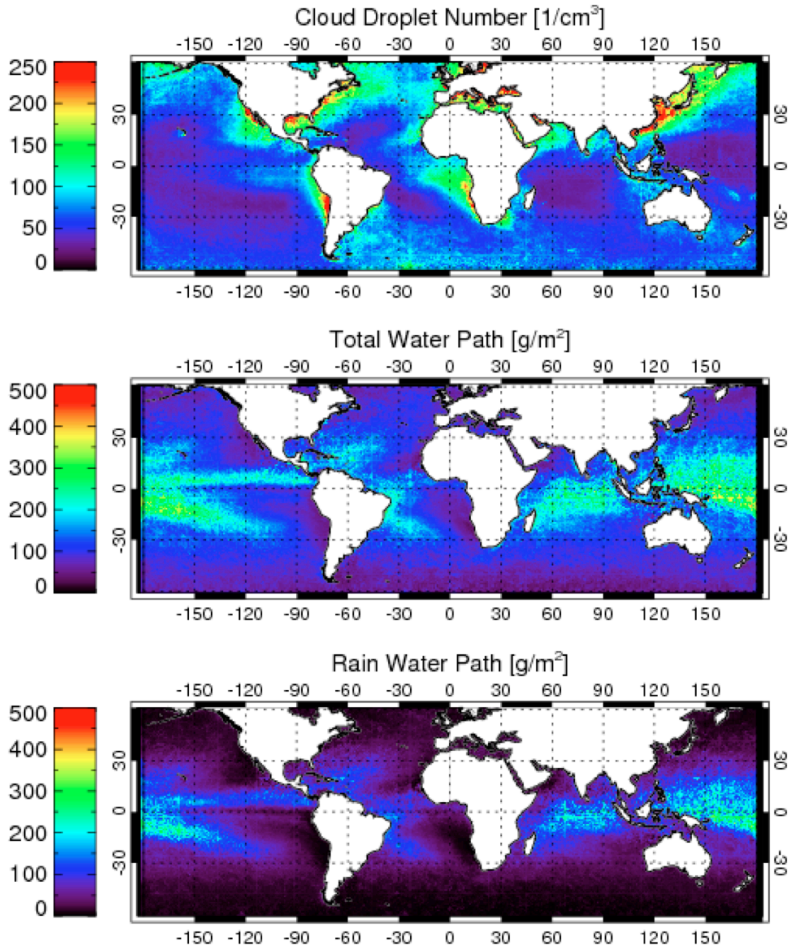
Auxiliary data, assumptions:

- Cloud top height
- Cloud top temperature
- Drizzle/rain particle size distribution
- Width of cloud droplet spectrum

Basic physical relations

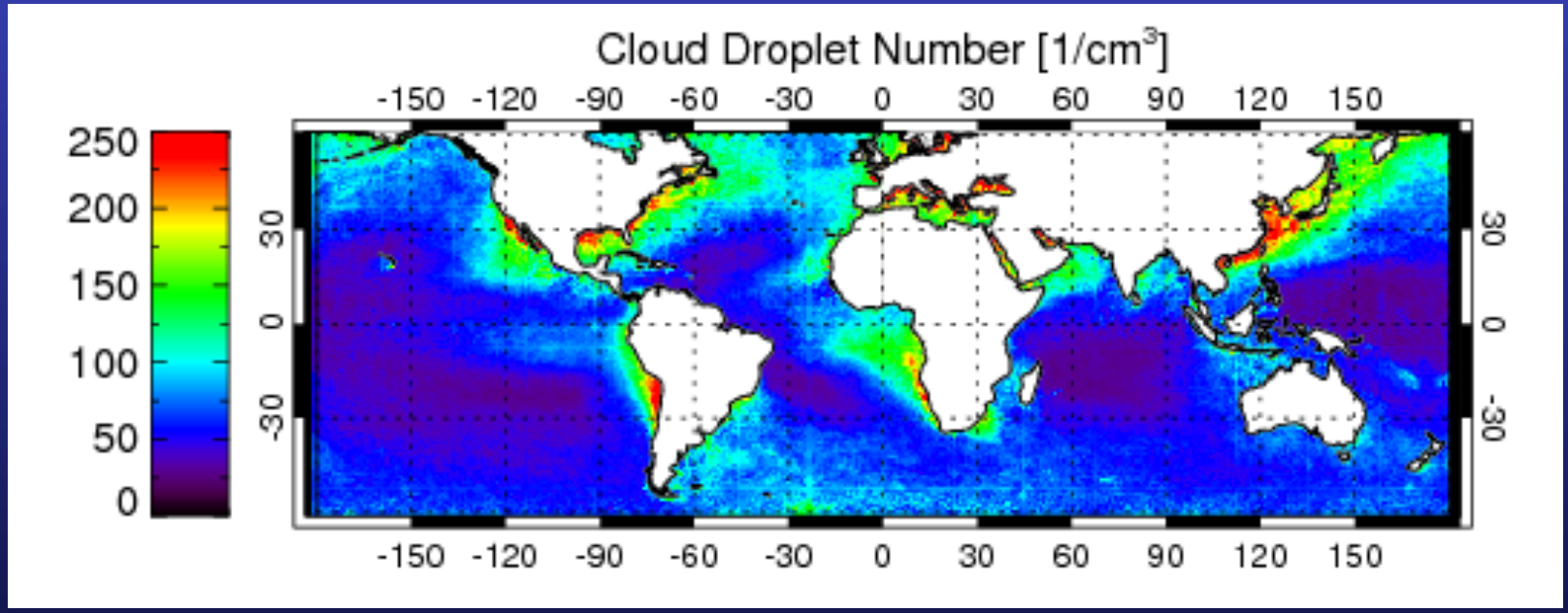
- Direct physical relationship between MW/VNIR optical properties and cloud physical properties.
- Errors and uncertainties due to input and auxiliary parameters can be specified and dependencies can be explicitly spelled out.
- Validity of assumptions can be assessed from observations.
- No unknown unknowns (though a lot of known unknowns).

Products

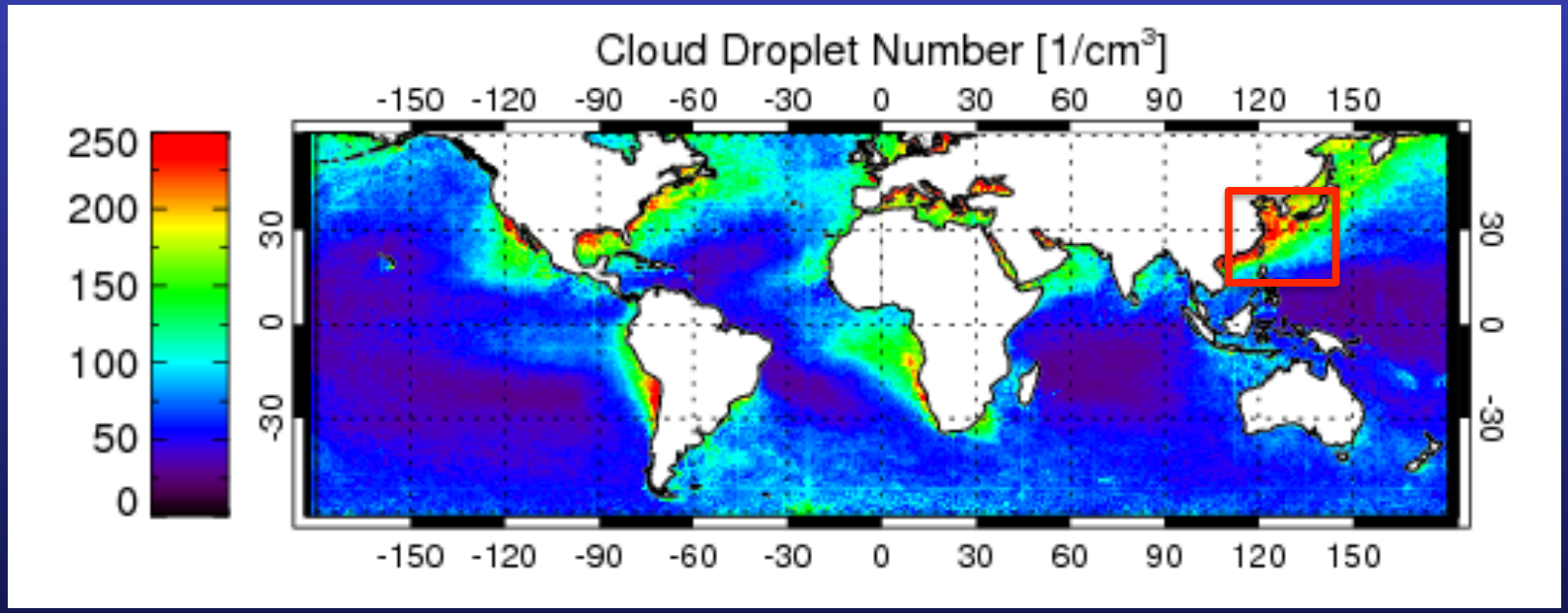


Bennartz et al. (2010), Bennartz (2007), Rausch et al. (2010)

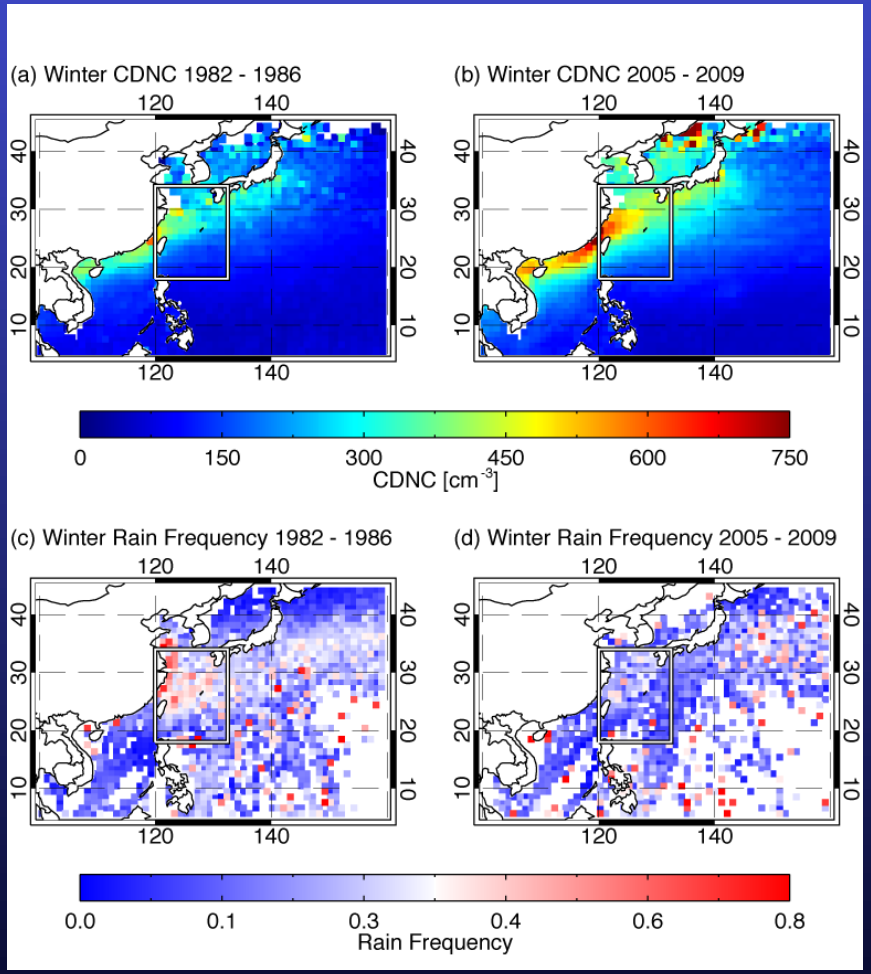
Cloud droplet number concentration

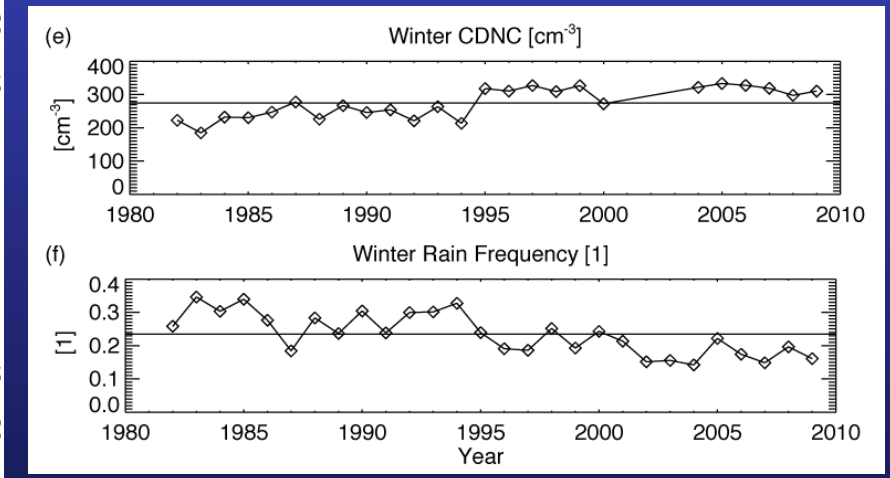


Cloud droplet number concentration



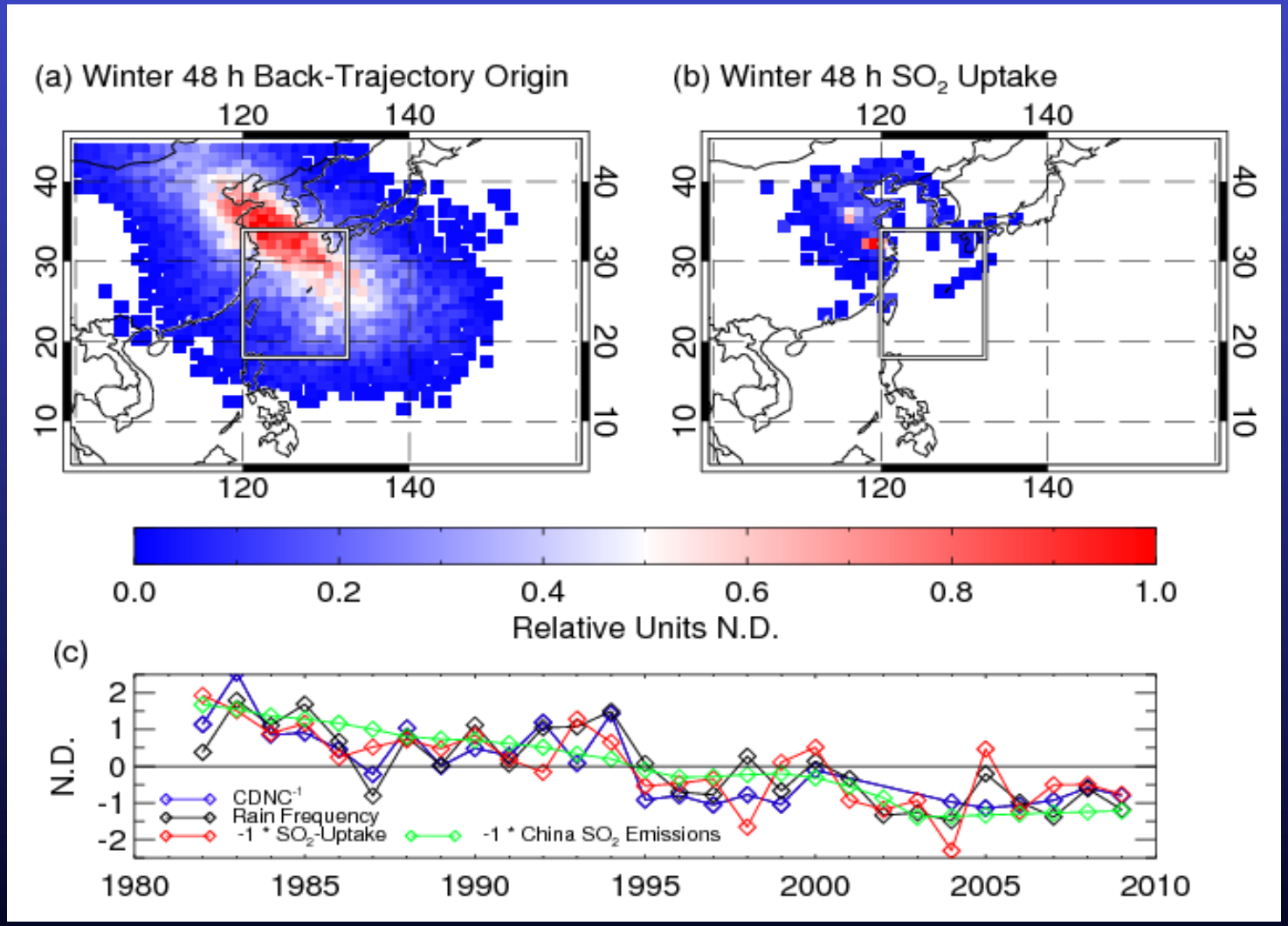
Cloud droplet number concentration





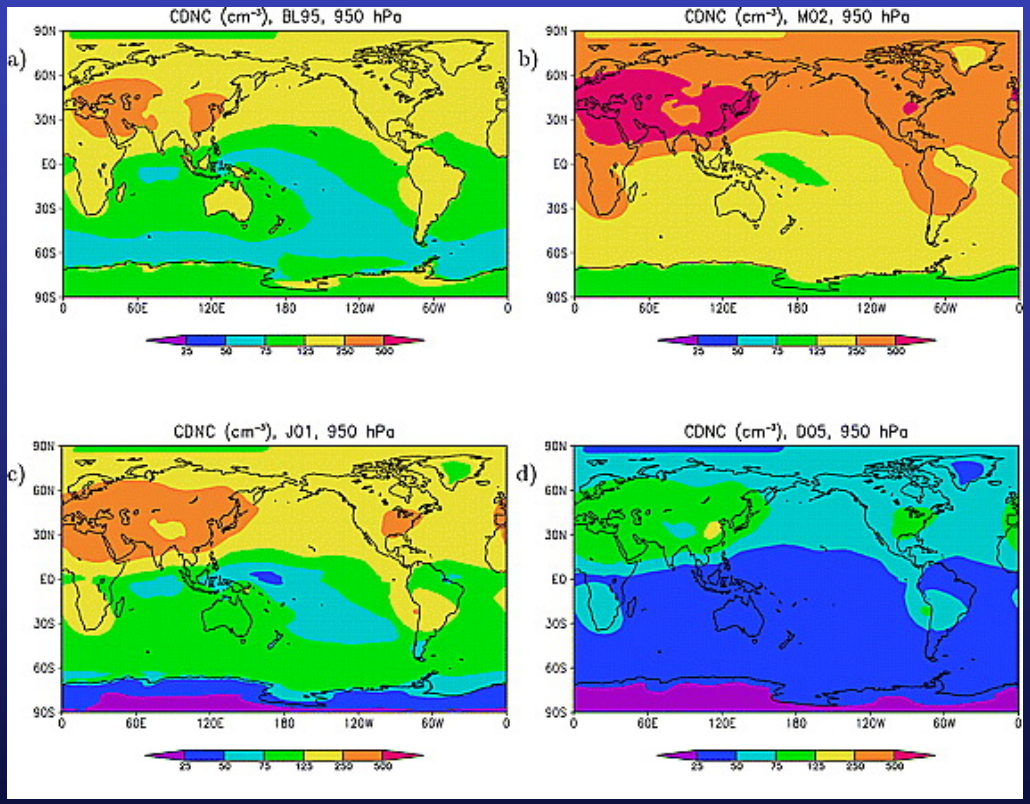
Bennartz et al. (2011)

Cloud droplet number concentration

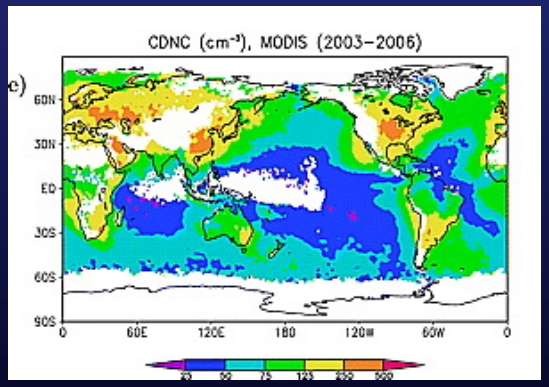


Bennartz et al. (2011)

Application example: Constraining cloud-aerosol interaction processes in GCMs

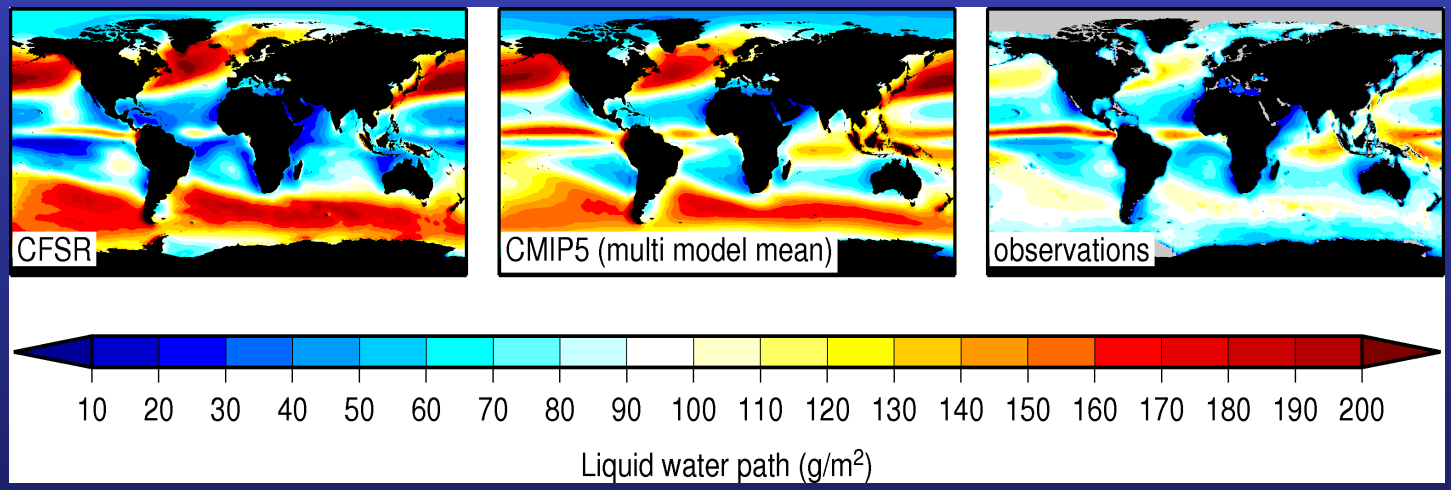


Differences in cloud droplet activation account for about 65 % (1.3 W/m^2) of the total spread in shortwave forcing (2 W/m^2) in IPCC AR4 models

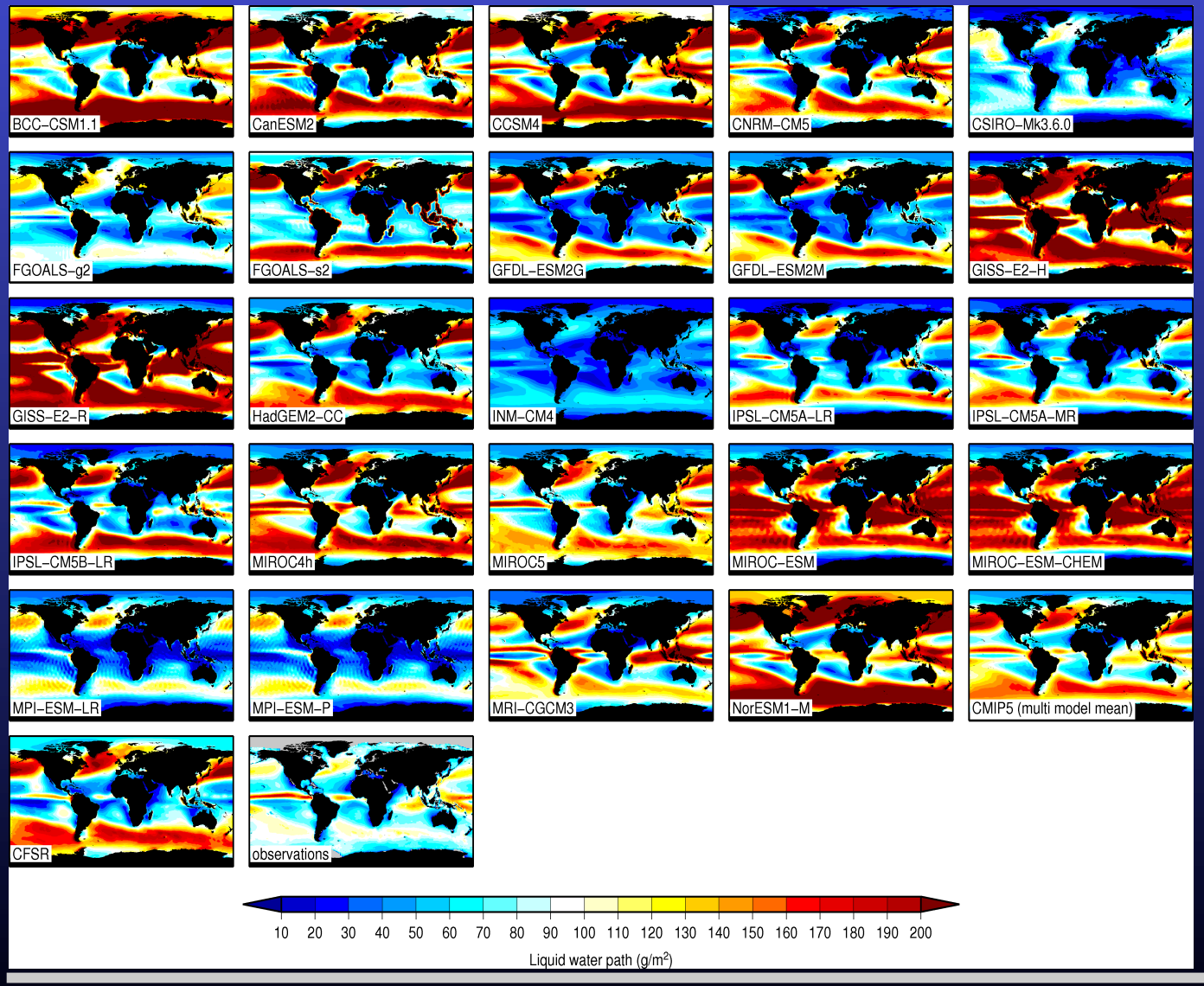


Storelvmo, Lohmann, Bennartz (2009)

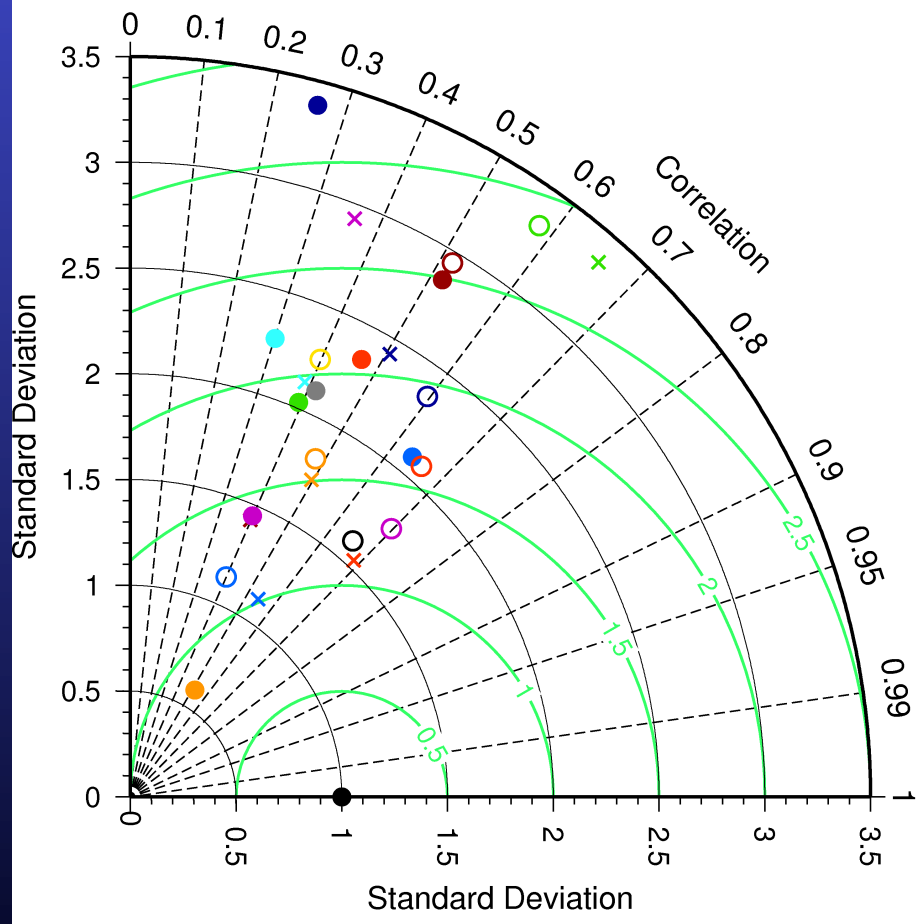
Validating models: LWP observations against GCMs



CMIP-5/CFS validation



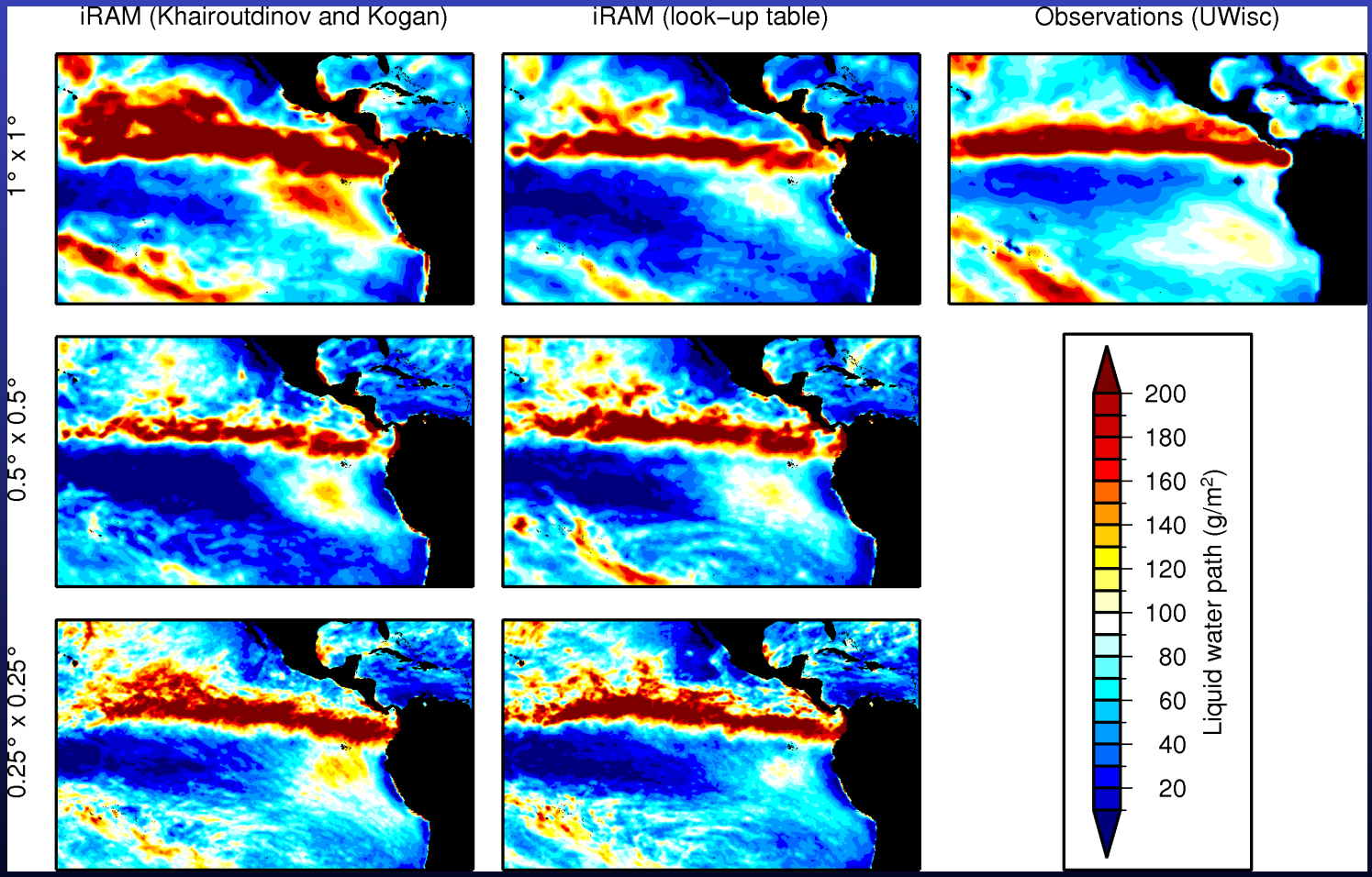
CMIP-5/CFS validation



- BCC–CSM1.1
- CanESM2
- CCSM4
- CNRM–CM5
- CSIRO–Mk3.6.0
- FGOALS–g2
- FGOALS–s2
- GFDL–CM3
- GFDL–ESM2G
- GFDL–ESM2M
- GISS–E2–H
- GISS–E2–R
- HadCM3
- HadGEM2–CC
- HadGEM2–ES
- INM–CM4
- IPSL–CM5A–LR
- IPSL–CM5A–MR
- IPSL–CM5B–LR
- MIROC4h
- MIROC5
- MIROC–ESM
- MIROC–ESM–CHEM
- MPI–ESM–LR
- MPI–ESM–P
- MRI–CGCM3
- NorESM1–M
- CFSR
- CMIP5 (multi model mean)
- observations

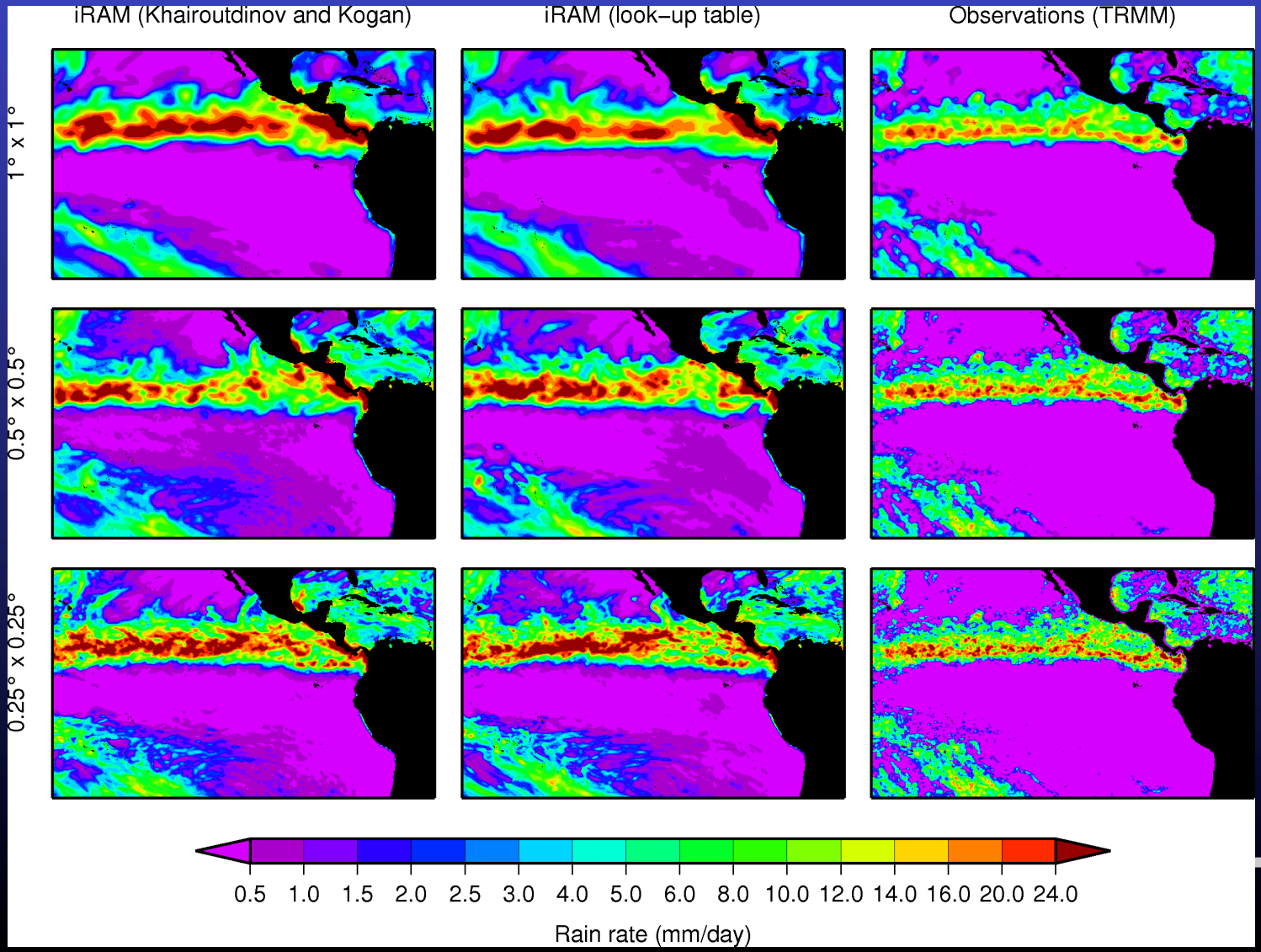
Accretion/Autoconversion

– Liquid water path (g/**m²**) –

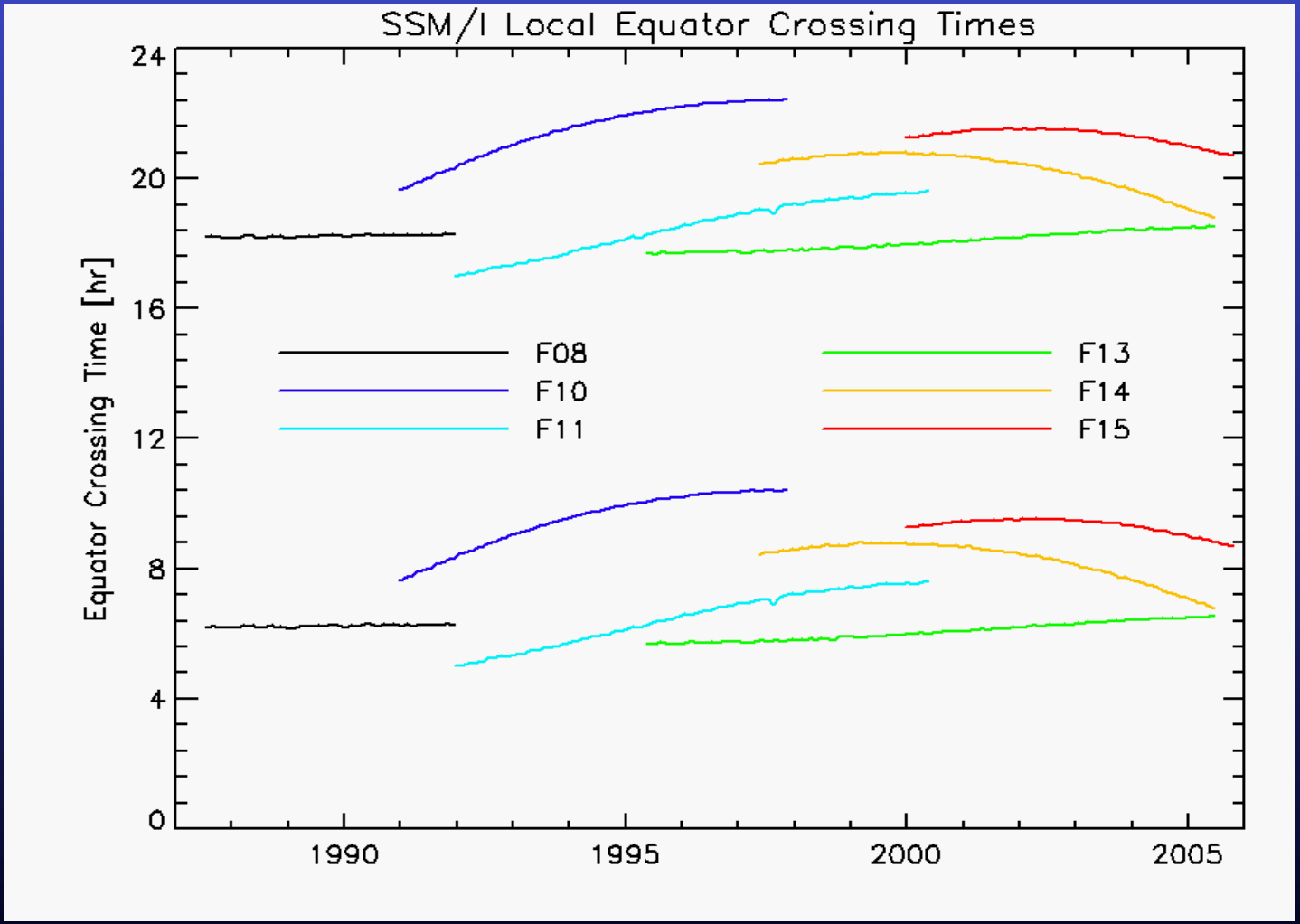


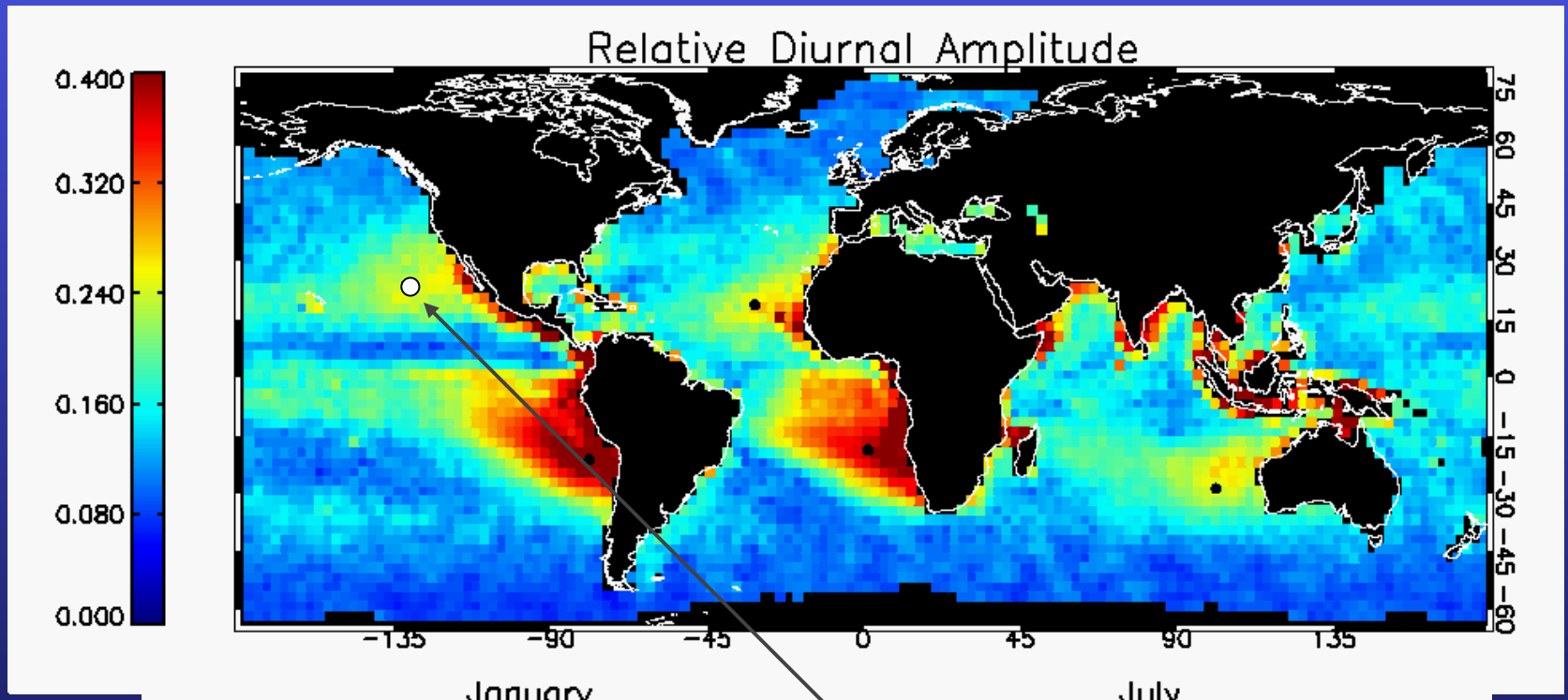
Accretion/Autoconversion

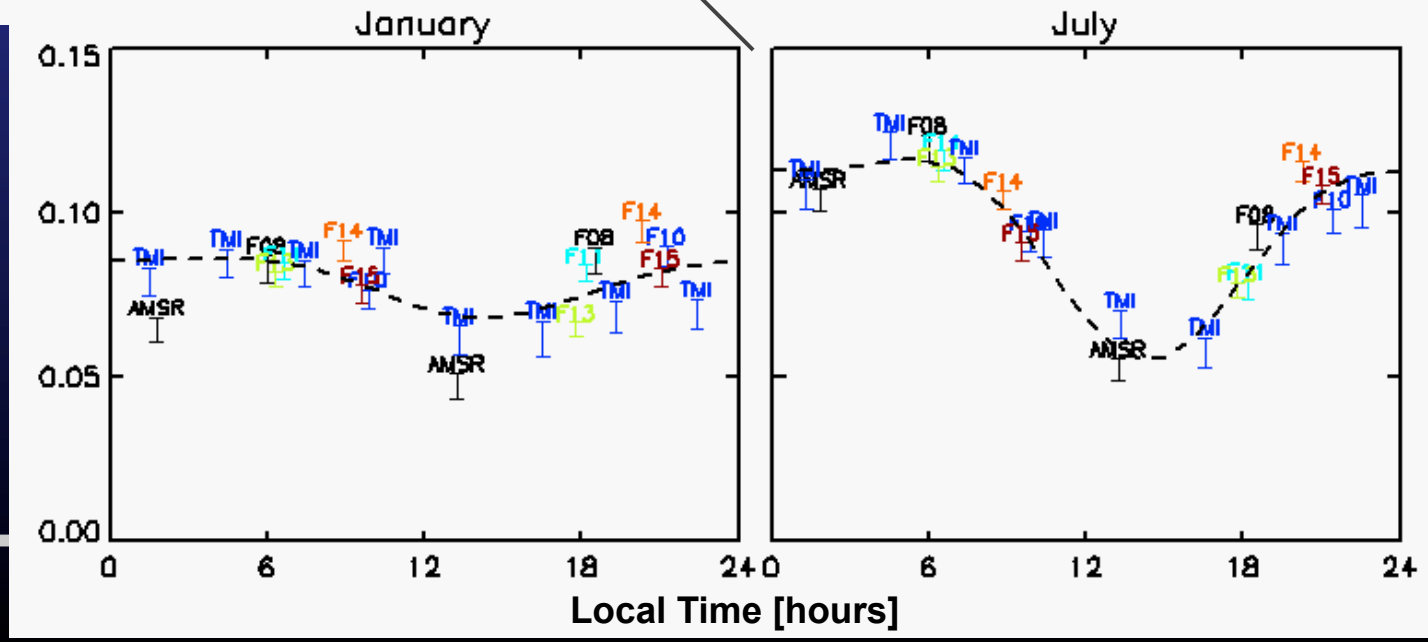
– Rain Rate (**mm/day**) –



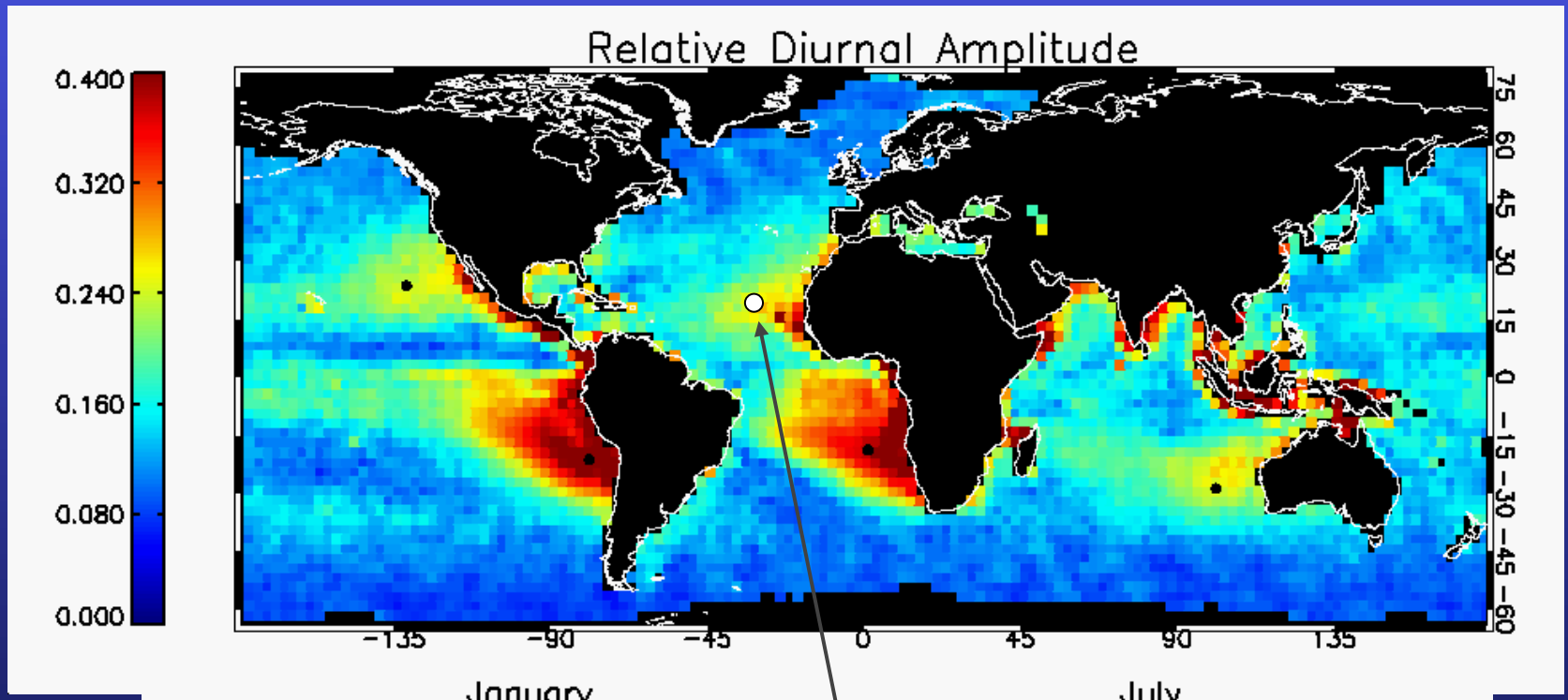
Special Sensor Microwave/Imager

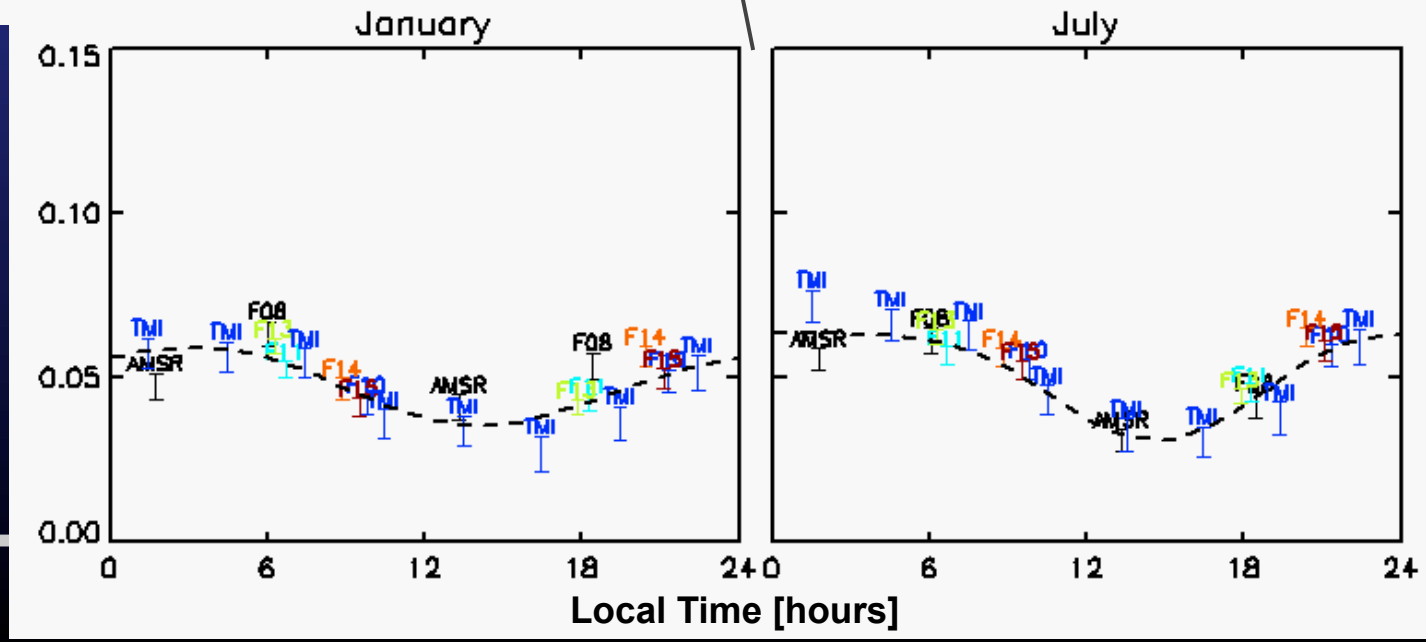




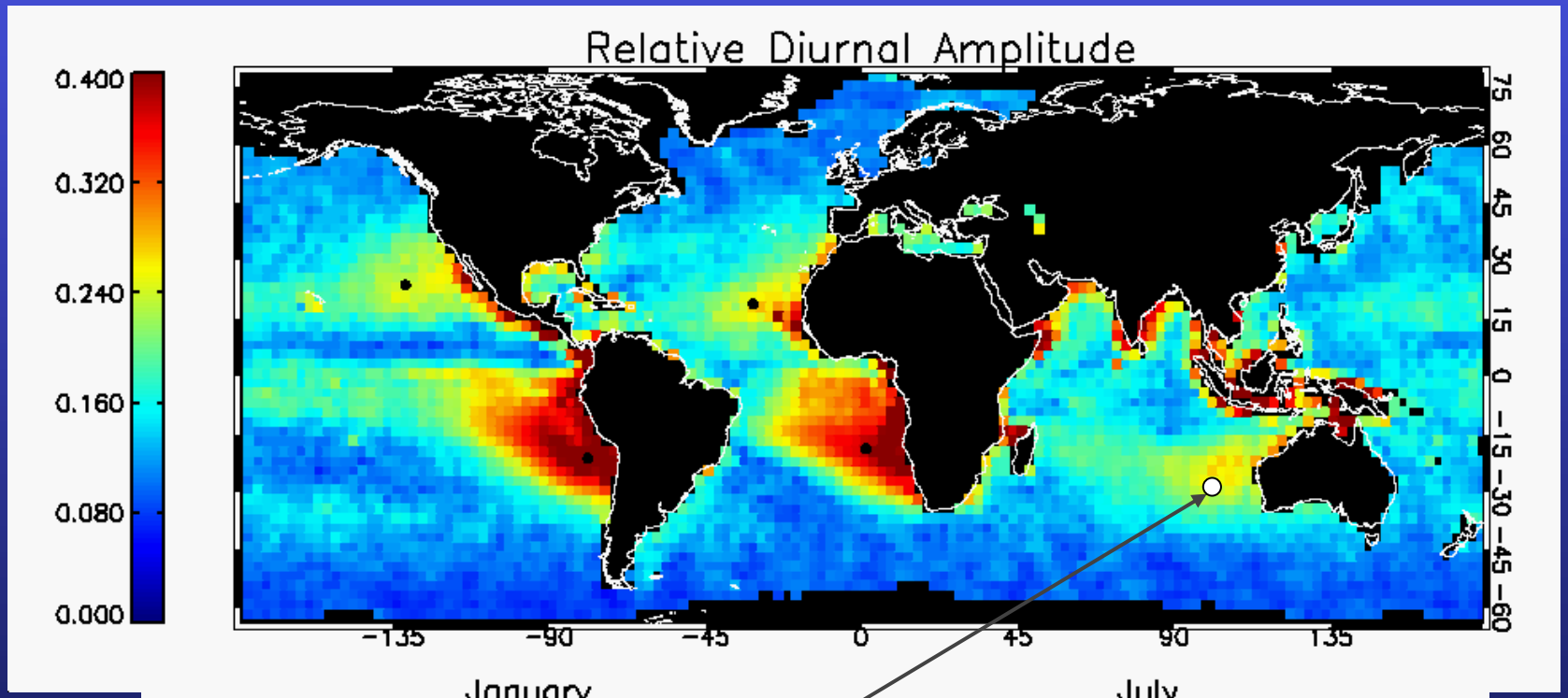


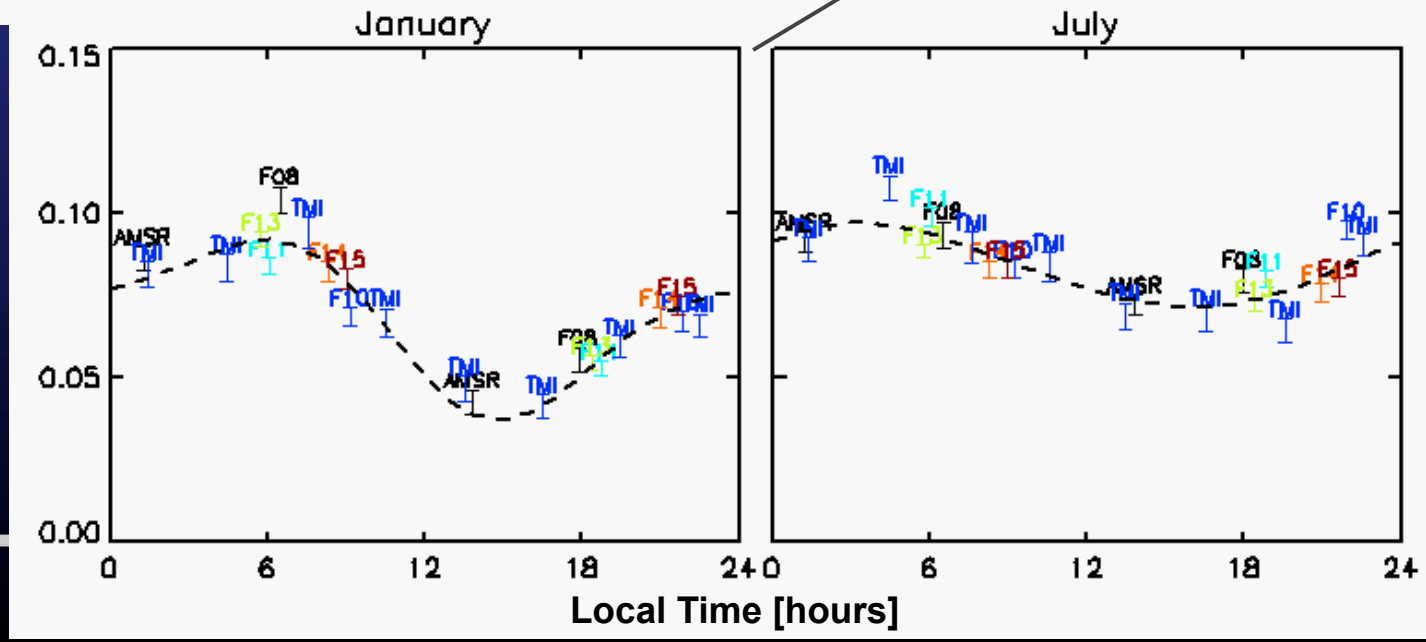
Liquid Water Path [kg/m²]



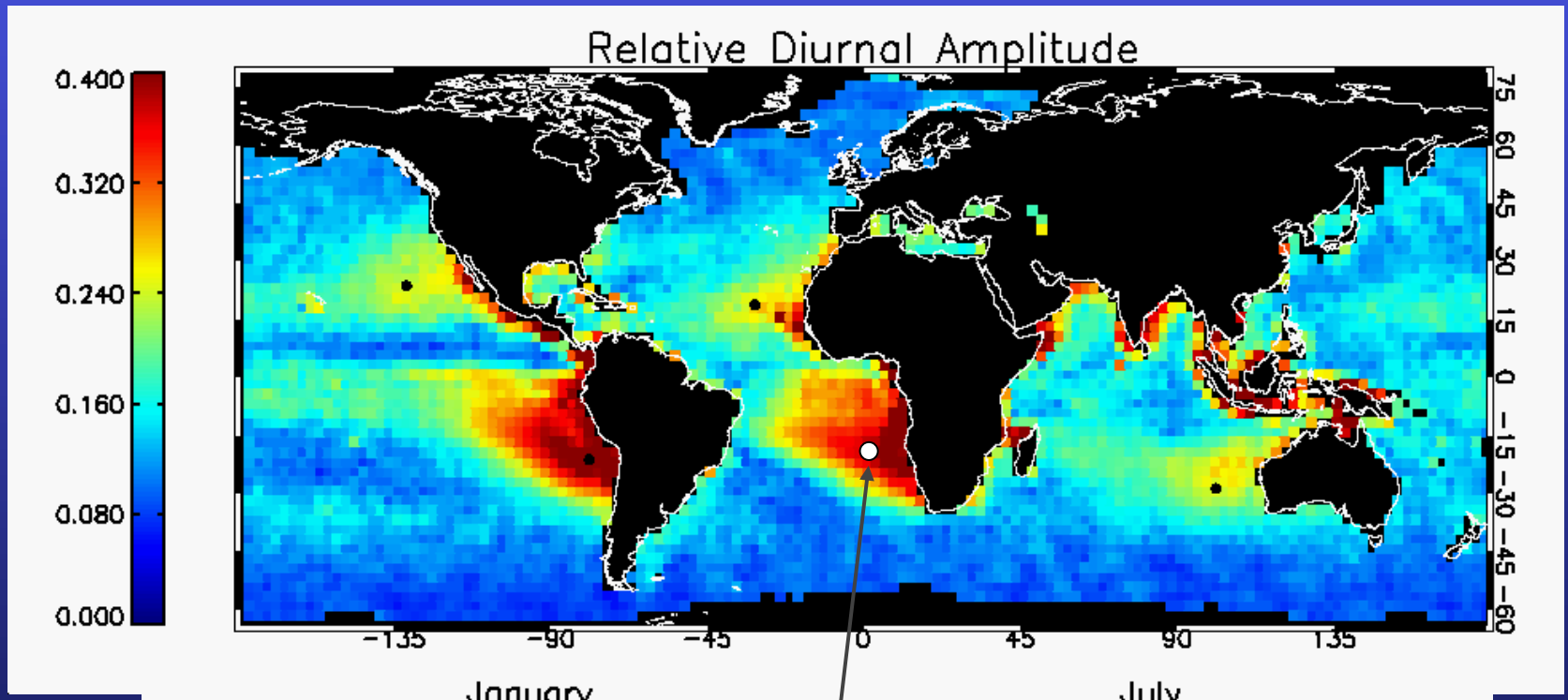


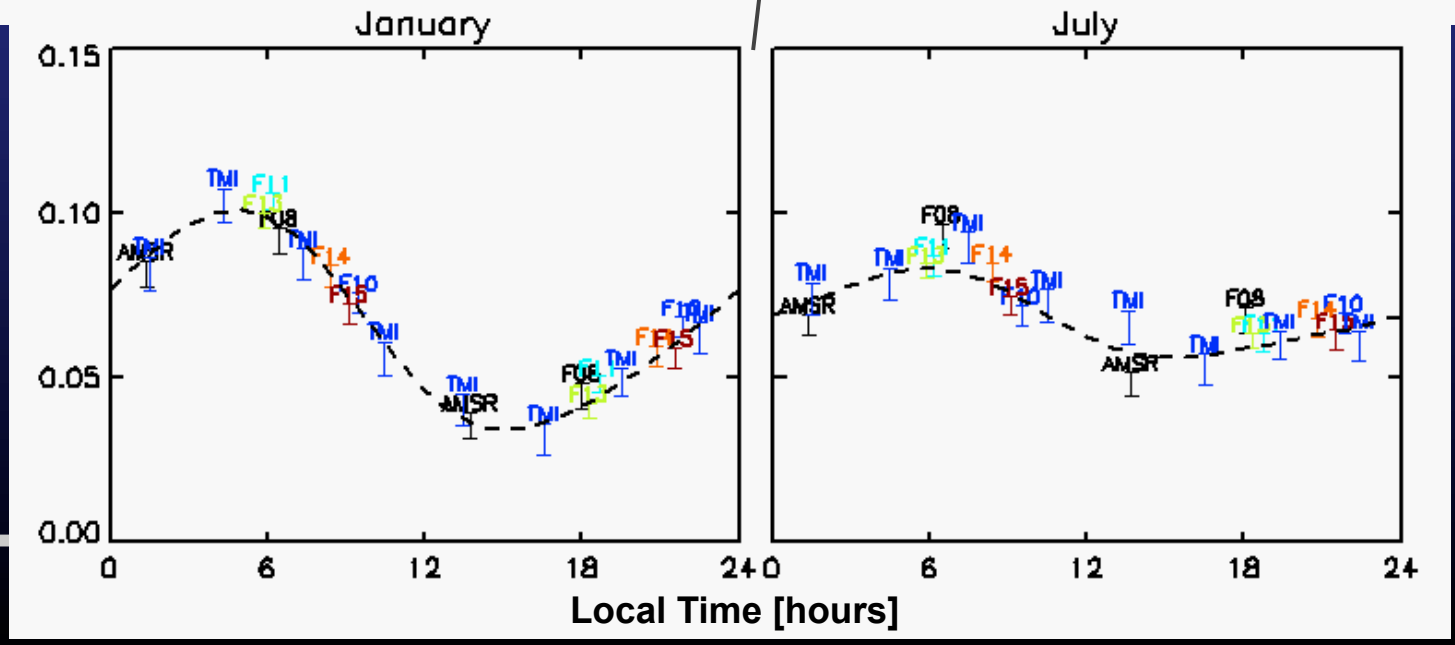
Liquid Water Path [kg/m²]



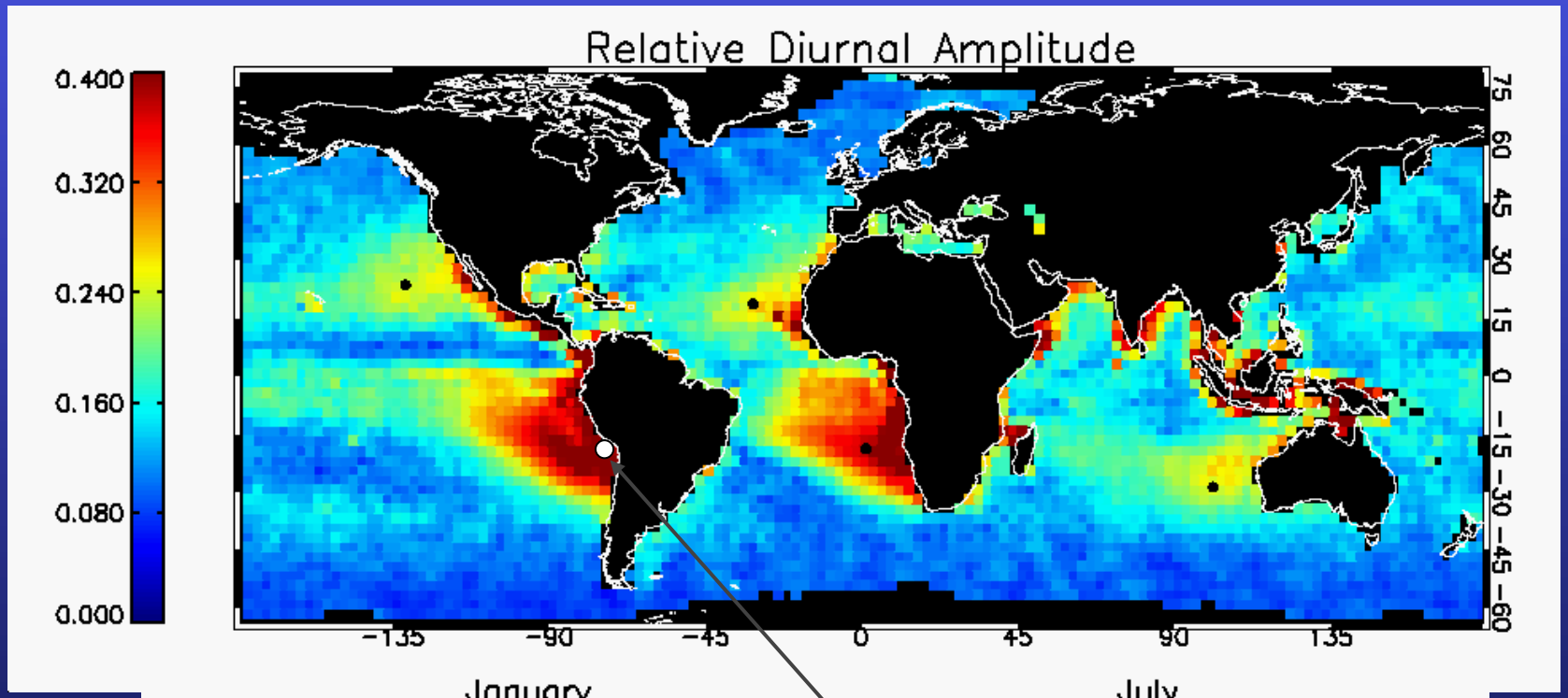


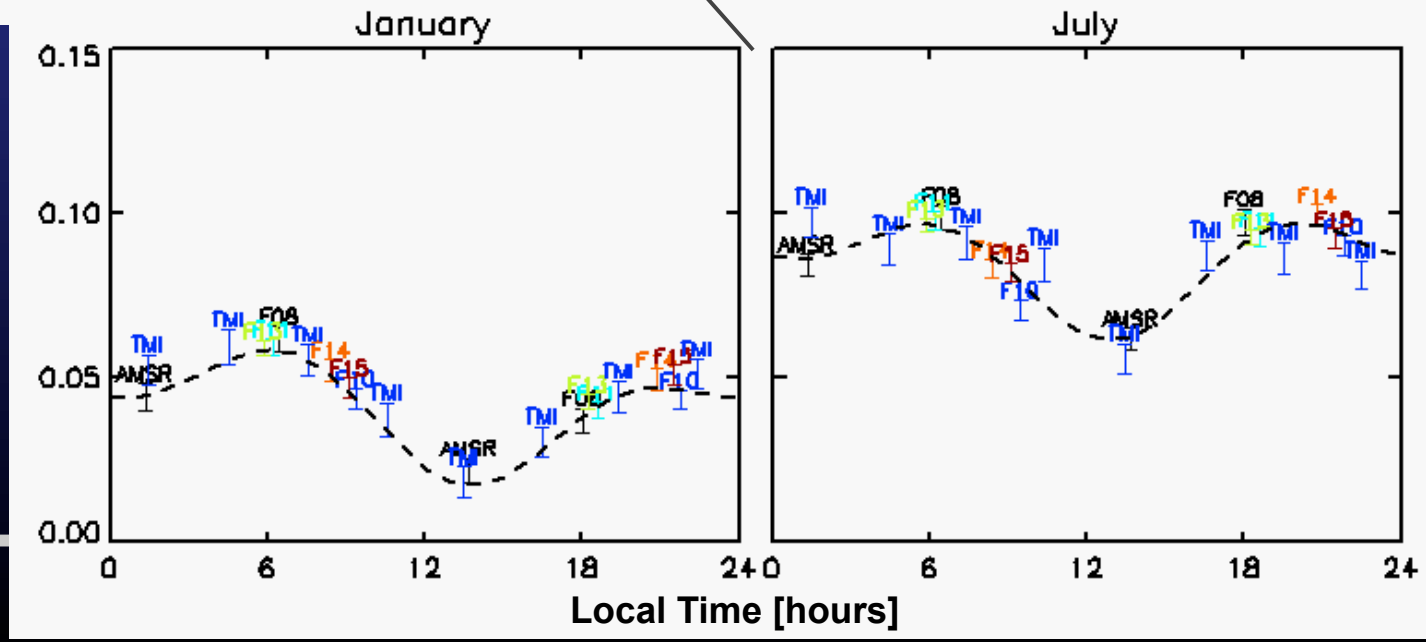
Liquid Water Path [kg/m^2]





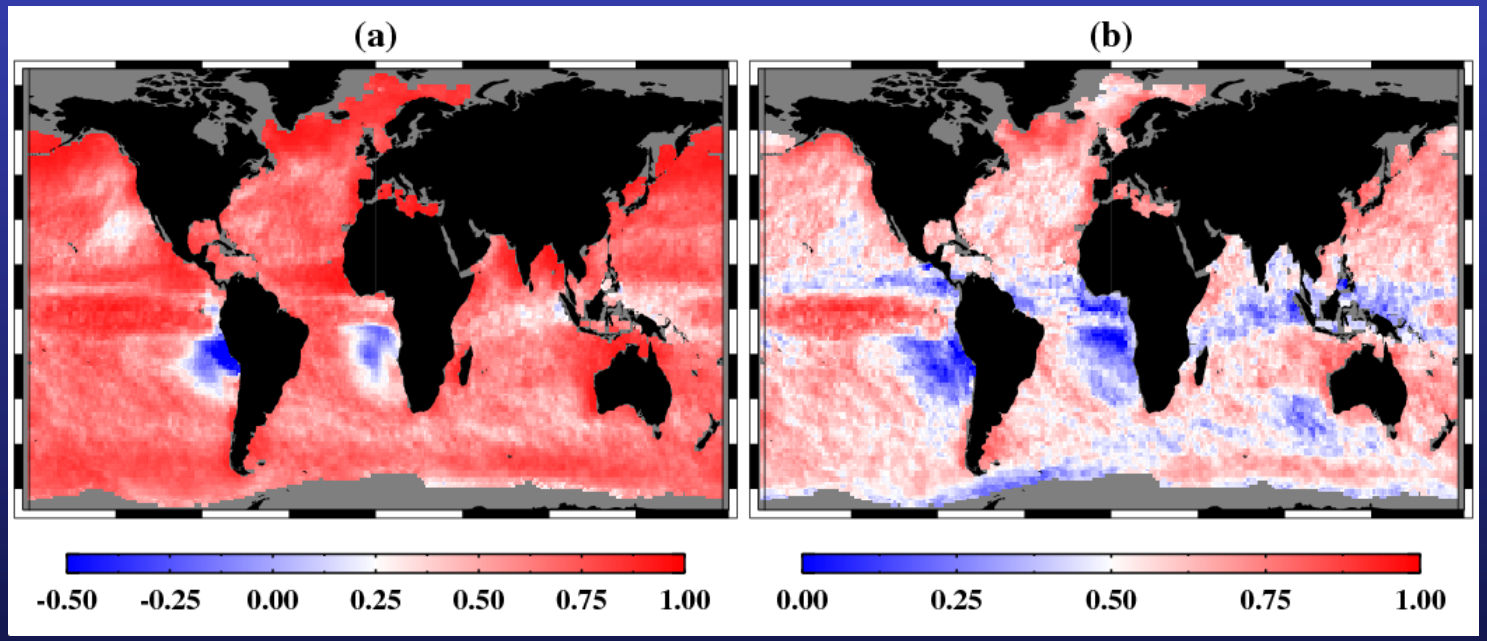
Liquid Water Path [kg/m^2]





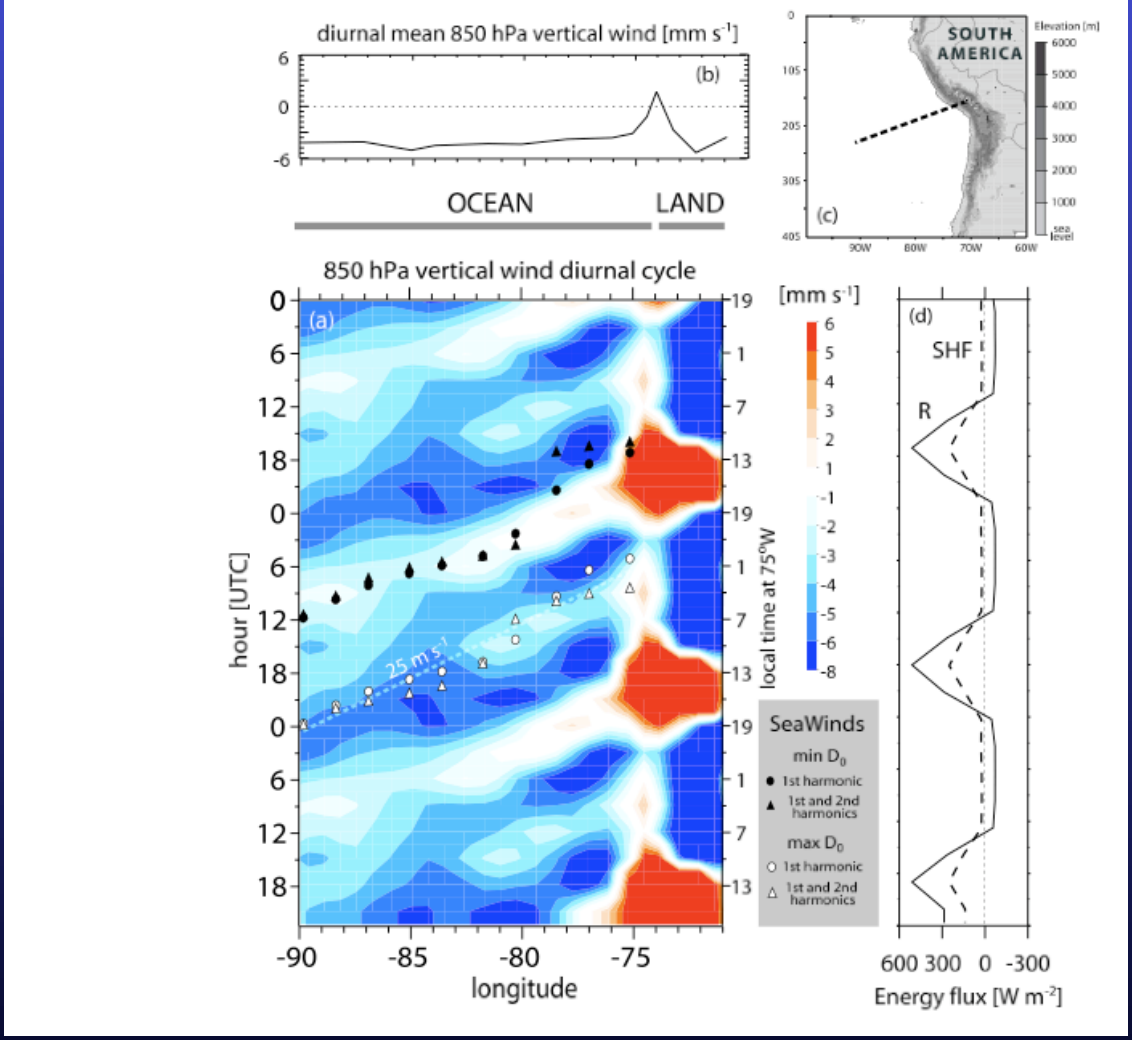
Liquid Water Path [kg/m^2]

Validating models: Correlation with ERA 40



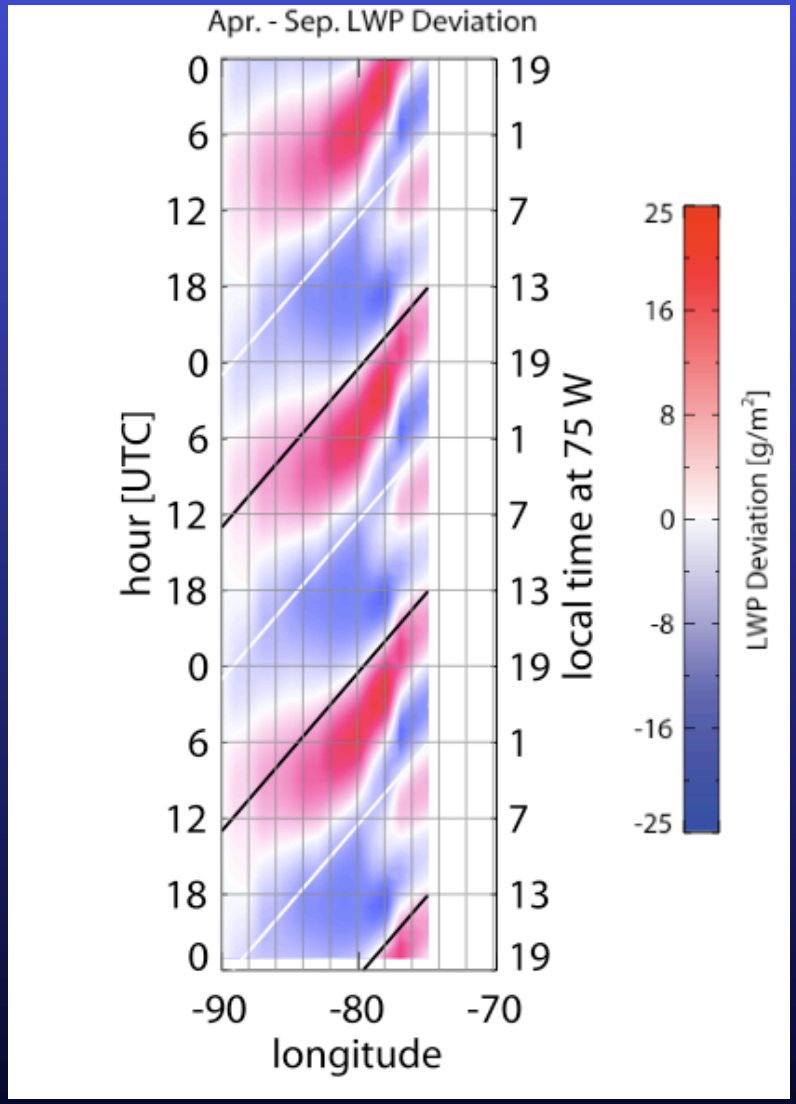
deseasonalized

O' Dell, Wentz, Bennartz, J Climate, 2008



Wood, Bennartz, Koehler, O'Dell, QJRMS 2009

Local Time [hours]



Wood, Bennartz, Koehler, O'Dell, QJRMS 2009

Local Time [hours]

Conclusions

- Satellite observations provide a wealth of information about cloud microphysical and radiative properties.
- In particular LWP, CDNC provide powerful constraints on warm cloud physics
- Caveats, uncertainties, and the limits of our current understanding need to be conveyed.
- Working closely with modeling community.

Acknowledgements

Collaborations T. Storelvmo (Yale), U. Lohmann (ETH), J. Rausch (UW-AOS), L. Borg, (UW-AOS), A. Heidinger, (NOAA), M. Foster (CIMSS), R. Leung (PNNL), J. Fan (PNNL), C. O'Dell (CSU), R. Wood (UW)

Funding: NASA MODIS Science Team, NOAA/Joint Center for Satellite Data Assimilation, DOE Regional Climate Modeling